Volume 26 July 1940 *Number 7*

Lubrication

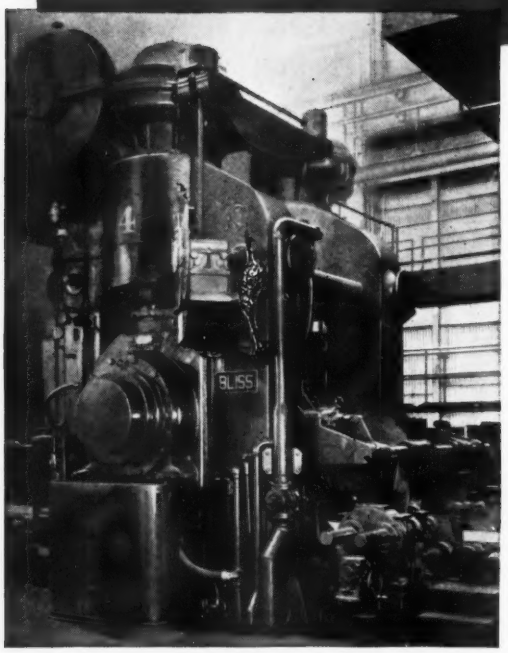
A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Heavy Duty Oil Circulating Systems in the Steel and Paper Industries

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

Sleeve Type Steel Mill Roll Neck Bearings Require Special Care



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TO KEEP oil-film roll-neck bearings at their highest efficiency so that the mill will roll to gauge, save power, and operate with negligible wear, it is necessary to use an oil highly resistant to oxidation, emulsification, sludging . . . one that separates rapidly from water and contaminating foreign matter.

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Heavy Duty Oil Circulating Systems in the Steel and Paper Industries

WHEN the automotive industry became a major factor in the progress of America, steel rolling mills speeded up to keep pace. When we became the most advanced reading public in the world, paper mill production likewise kept pace.

The meaning of speed in this connection can be appreciated when we note that the modern cold strip steel mill today can produce strip steel at a rate of 2300 feet per minute—an increase of some 2000 feet in scarcely ten years. Paper, in turn, can be manufactured in widths up to 25 feet at speeds of approximately 1500 feet per minute.

Translated into conventional figures, this means some 550 miles of strip steel from three to four feet wide per day; and 275 tons of newsprint paper per machine. And there are dozens of machines nearly as large in daily production.

All this means that such machinery has had to be designed to operate at continually higher speeds. It led to most careful consideration of bearing materials, methods of lubrication, and means for preserving the lubricating ability of oils in service.

So we approach the lubrication of the rolling mill in steel, and the paper machine in full realization that speed conditions require careful consideration of oil viscosity; that the possibility of water contamination requires careful sealing; that high temperature may cause oxidation; and that means for lubricant protection must be considered from the time the design is laid out in the drafting room.

Builders of oil filtration and purification equipment have extended the utmost cooperation in developing the latter. Bearing designers have produced mirror finish surfaces and heavy duty roller bearings to carry the loads without undue increase in oil viscosity, and the petroleum industry has organized its research and refinery programs so that oils of maximum chemical stability can be available.

But a few years ago, oils of steam turbine grade, showing 1620 demulsibility and high oxidation-resistance, were limited to about 500 seconds Saybolt Universal viscosity, or below, at 100 degrees Fahr. Today they can be produced up to 2500 S.S.U. The sleeve-type oil-film bearing dictated these requirements; the petroleum industry accepted the responsibility.

THE PAPER MACHINE

The dryer end section of the paper machine offered one of the most promising points for improvement in means of lubrication by application of oil circulation, with provision for adequate and continuous reconditioning. This became all the more apparent with the application of the heavy duty roller bearing and the attendant means which the bearing engineers provided for oil sealing. It presented a set-up which would benefit materially through oil lubrication, supplied under controlled pressure at sufficient volume to flood the bearings continually, the oil thereby serving as a heat transfer agent, as well as a flushing medium. It only required study on the part of oil filter designers to complete the system and maintain

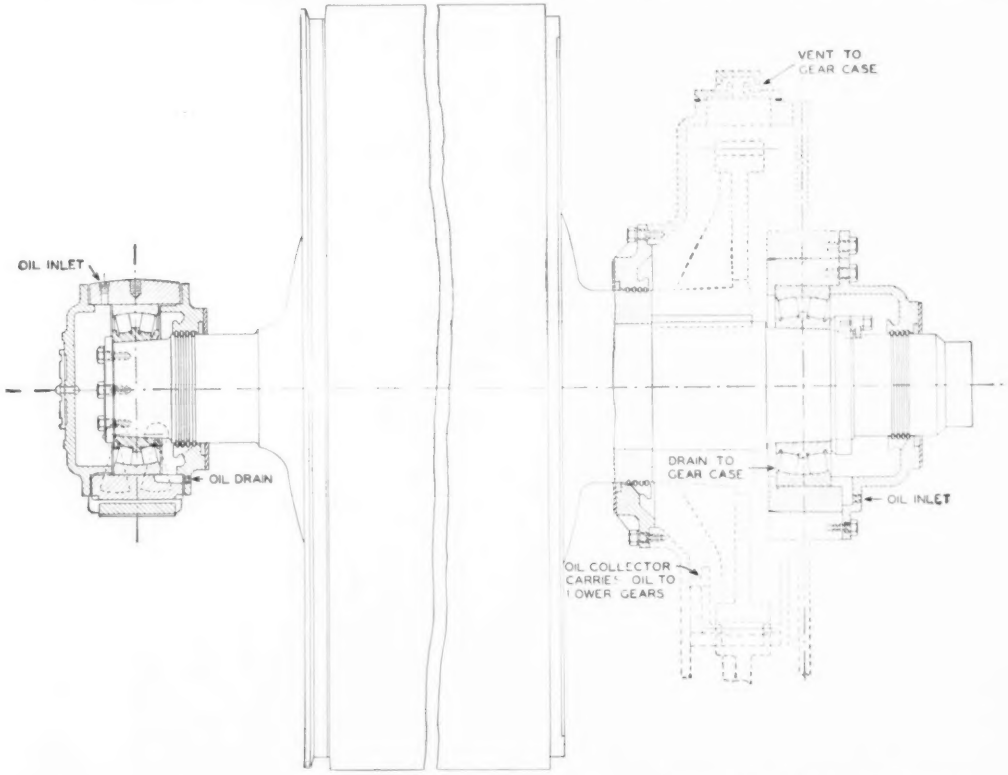
the oil in service at a sufficient degree of cleanliness to insure its lubricating ability.

The possibility of oil contamination becomes more remote as the paper approaches its finished state, in passing over the various rolls included in the dryer section. Water and wet stock are absent; also this part of the mill is clearly beyond comparison with many other operations. One is concerned, however, with the high temperatures which may prevail, especially if the machine is to be run at high speed to meet high production schedules. Then they literally "turn on the heat" to speed up the rate of drying to conform to the running speed of the machine.

Heat is one of the contributing causes of oil oxidation, especially if the oil is exposed to air and metallic particles. Oxidation is evidenced by sludge accumulations and increase in the neutralization number of the oil. The latter indicates that the oil has become definitely acid in nature.

Arrangement for Lubrication

The oil circulating system, as designed for the modern paper machine, has required the most careful engineering in planning the distributing and return piping, tankage for the oil storage and filtration unit, and pumps of adequate capacity to keep a full stream flowing through the bearings all the while the machine is in motion.



Courtesy of The Pusey & Jones Corporation

Fig. 1—Dryer bearing arrangement of SKF spherical roller bearings on a Pusey & Jones paper machine. The bearing housing design allows for free flow of oil, with no chance for accumulation of non lubricating deposits. The same oil serves the drive gears, as well as the bearings under controlled pressure and in controlled volume.

Temperature control is also an important factor. It is obvious that the circulation of even low pressure steam through the dryer rolls must lead to a heat condition at the bearings which can be controlled only by the cooling effect of flood lubrication, supplemented by water cooling of the oil in the return tank.

STEEL ROLLING

There has been considerable similarity between the bearing research of the steel and paper industries in planning for circulating lubrication. It was found that the roller bearing and the tapered neck sleeve type bearing were equally as effective. Their perfection led to the requirement of lubricating oils of maximum chemical stability to meet the fluctuating speed, load, and water conditions. The advantages incident to continuous circulation of comparatively fluid oils were immedi-

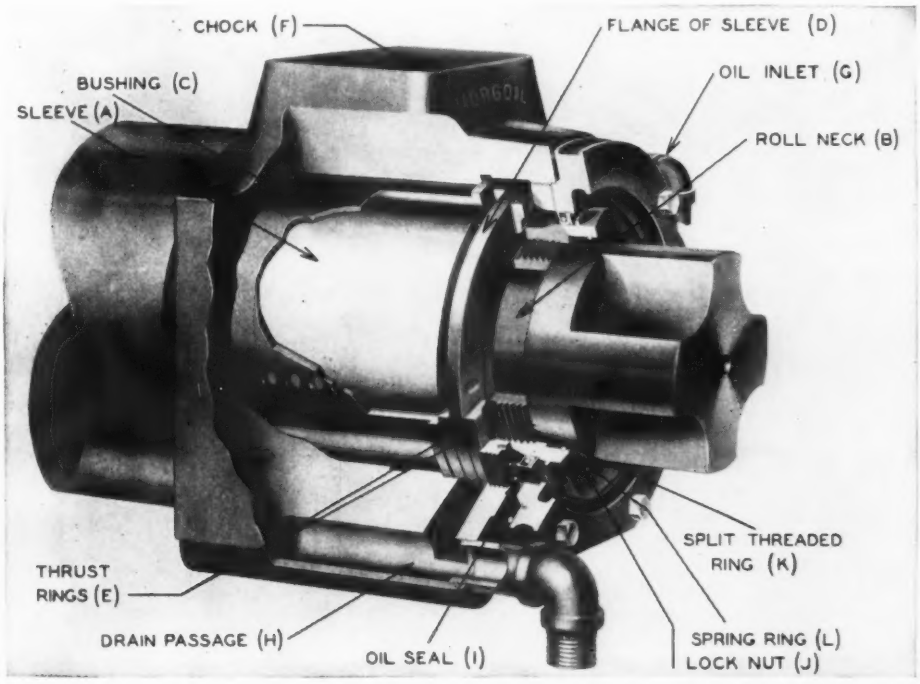
ately obvious with this development and the design of lubricating systems capable of serving both gears and bearings with the same oil.

Probably the most important characteristic in such an oil, coupled with resistance to oxidation, is resistance to emulsification, although the latter is gradually becoming secondary as builders provide more effective seals to keep out the water. Modern construction makes use of specially designed seals, to reduce this possibility of water contamination. Tight fitting brass rings, leather cup seals, felt or rubber can be used, according to the design of the bearing. It has also been found practicable to install leather cup seals in pairs or back-to-back.

All these protective measures promote more dependable lubrication. This permits of more practicable application of the theories of lubrication, one of which involves the relation of viscosity to speed; likewise, the viscosity at the operating temperature. When viscosity was first considered as a specification for oils for such service, the viscosity index seemed quite important, as it denoted the slope of the viscosity-temperature curve. When observed over the relatively narrow range of operating temperatures, within which many oils in a circulating system must function, viz., from around 90 to 130, the difference in operating viscosity is proportionately reduced; then the viscosity with respect to speed, the chemical stability, and the demulsibility require prior attention.

One of the theories of lubrication states that the viscosity should vary inversely as the speed. So, in a variable speed, continuous strip steel mill where the speed at the roughing end is low, a heavy oil is necessary; the bearings on the finishing end, being subjected to higher roll speeds, should in turn be served with a lower viscosity oil. To meet these conditions, a range of from 250 to 2500 seconds Saybolt Universal Viscosity at 100 degrees Fahr., has been established by the builders of sleeve type bearings.

Under comparatively low speeds, the peripheral speed, as it affects the ability of the oil to free itself from entrained water, is important. This becomes more apparent with heavier oils, as these latter (after usage) do not free themselves from water as readily as do light oils.

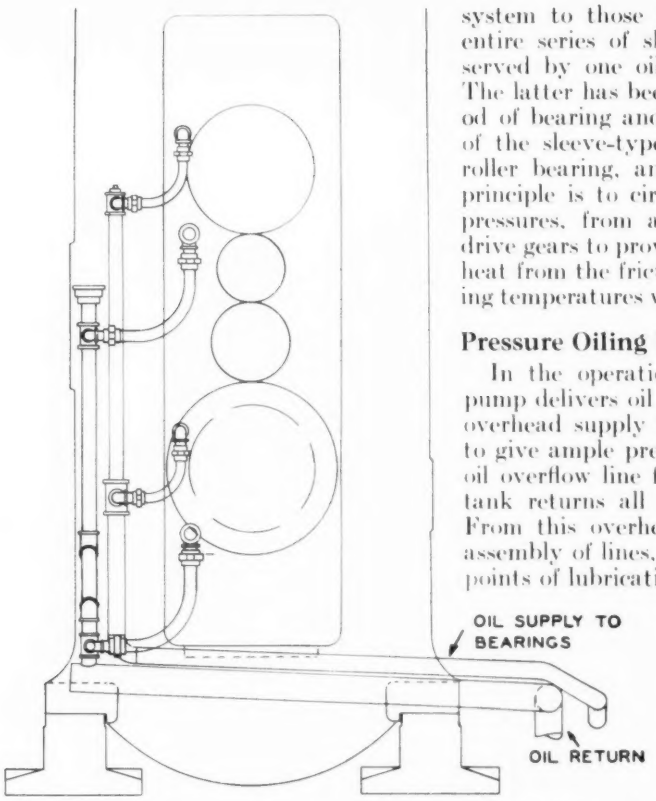


Courtesy of Morgan Construction Company

Fig. 2—Details of the MORGOIL tapered neck steel mill bearing. Sleeve A fits over and is keyed to the tapered roll neck B, thus becoming the journal. Bushing C surrounds this mirror-finish sleeve. Oil for maintenance of the lubricating film is delivered at G, and drained off via H. Other essential parts of this bearing are as indicated. Oil sealing has been given very careful attention.

THE MECHANICS OF OIL CIRCULATION

Circulation of fluid oils under uniform pressure conditions is conducive to these requirements, and helpful in reducing operating tem-



Courtesy of United Engineering and Foundry Company

Fig. 3—Drive side elevation of a United tandem cold mill showing arrangement of oil piping to the Morgoil bearings.

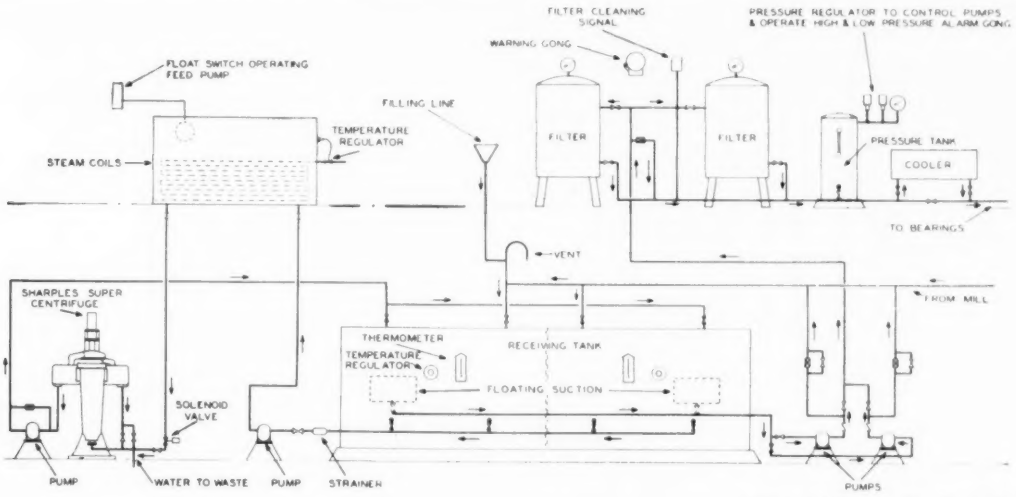
peratures through the cooling effect of an excess of fresh cool oil. As a result, a variety of combinations were soon developed, ranging in simplicity from the unit type of gravity feed system to those multiple power devices whereby an entire series of sleeve type or roller bearings can be served by one oil under the same constant pressure. The latter has been accepted as a most efficient method of bearing and gear lubrication with the perfection of the sleeve-type roll neck bearing, the heavy duty roller bearing, and the oil tight gear housing. The principle is to circulate cool, clean oil under uniform pressures, from a central reservoir, to bearings and drive gears to provide proper lubrication and to remove heat from the friction surfaces. This keeps the operating temperatures within reasonable limits.

Pressure Oiling by Gravity

In the operation of a gravity system, the supply pump delivers oil from the settling or sump tank to an overhead supply tank which is mounted high enough to give ample pressure to the gears and bearings. An oil overflow line from the overhead tank to the sump tank returns all surplus oil delivered by the pump. From this overhead tank, a supply line, through an assembly of lines, delivers oil by gravity to the various points of lubrication; the oil then returns by gravity to the sump tank located below the operating floor.

Gravity circulation reduces the intricacy in construction and the necessity for costly automatic controls, but it is limited in regard to available pressure due to plant conditions. Where this pressure is low, it may influence the choice of the viscosity of the oil.

With increase in pressure, the viscosity can be somewhat reduced. This reduction in body of the lubricating oil is compensated for by the added volume which becomes available through the in-



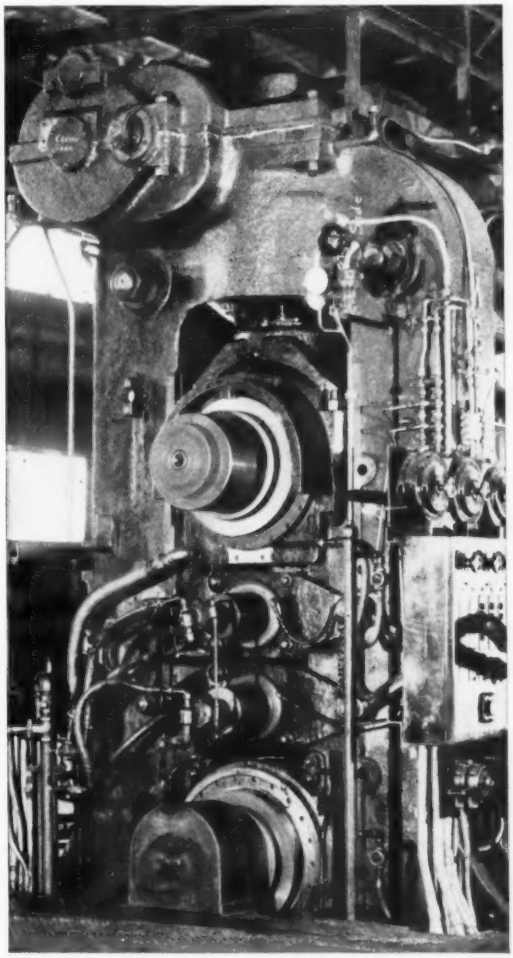
Courtesy of The Sharples Corporation

Fig. 4.—Diagramatic layout of a Sharples lubricating oil system for steel mill service. Note essential parts and direction of oil flow, as indicated by arrows.

creased pressure under which the oil is delivered to the bearings.

Full Pressure Lubrication

This method of lubrication is applicable to paper machine roller bearings and to the gear



Courtesy of Mesta Machine Company

Fig. 5—End view of a Mesta mill equipped with Mesta sleeve-type oil film lubricated bearings. Note assembly of piping essential to oil circulation.

units and oil film bearings in steel rolling, because of its pronounced flexibility. The supply pump delivers oil at a predetermined pressure from the settling tank to a pressure tank in which an air cushion is provided at the top. Usually two pumps are provided, one of which may serve as a spare. This latter cuts in automatically, by means of electrically operated pressure switches when the pressure in the pressure tank drops below a predetermined minimum, due to failure of the operating pump, or whenever the latter is unable to maintain the desired pressure. If both pumps fail or are unable to maintain sufficient pressure, a third pressure switch, which is set just below the minimum operating pressure required, sounds an alarm.

The expansive action of the air cushion in the pressure tank forces the oil through the main supply line and the numerous branch lines; these are equipped with orifice plates or valves, to provide each bearing or gear unit with its proper share of lubricant. Frequently each of the various points of lubrication are equipped with a pressure switch and light signal to warn the operator, should the oil flow be interrupted. The return oil from the gears or bearings flows back to the settling tank by gravity; here it is subjected to filtration and purification to fit it for recirculation.

Pressure Control

Oil pressure in a pressure lubricating system must be carefully controlled within the limits established by the machine designer; usually from 5 to 15 pounds will prevail. Excessive increase in the pressure under which oil is delivered to bearings may cause seal leakage. Then loss of oil, and possible entry of water would more than offset the cooling benefits of the increased volume of oil delivered. Most effectual lubrication in a circulating system results when the oil is kept as free from water as possible. This is one reason why elaborate systems of filtration and centrifuging are employed in the steel and paper industries.

Constructional Details of the Circulating System

The Oil Cooler

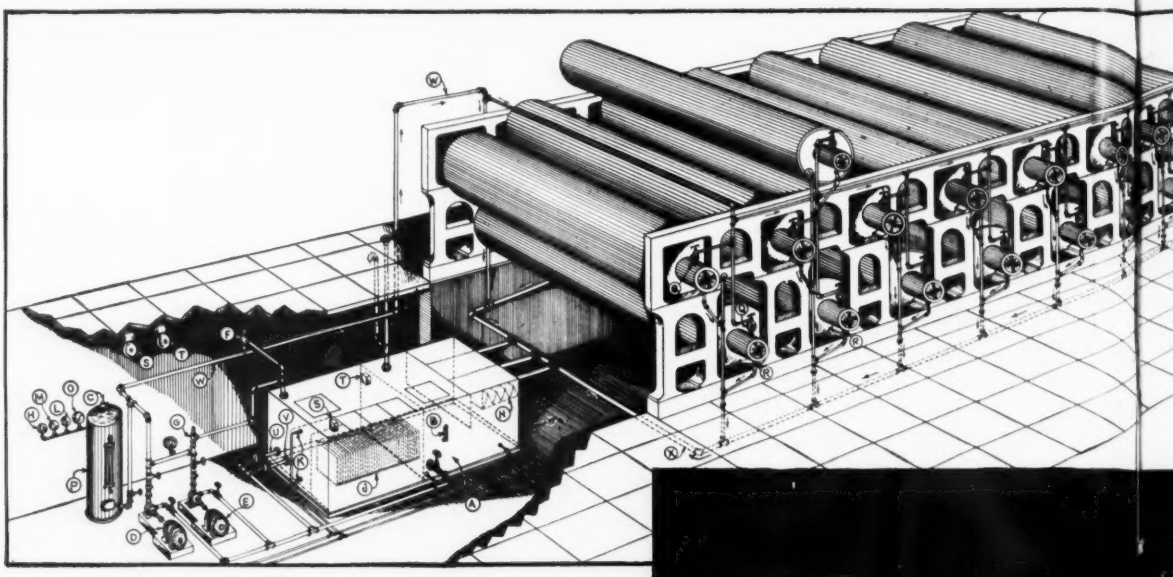
An oil cooler of ample size is provided to lower the temperature of the oil leaving the pressure tank. For best results, an ample supply of cooling water must be provided for the cooler, and the latter must be kept clean. Thermometers inserted in the oil lines entering and leaving the cooler serve as indicators as to the efficiency of the cooler.

Oil Filters

Pressure filters installed between the pumps and the pressure tank remove any foreign matter that might remain in the oil drawn from the settling tank. Filters of the latest design have a self-cleaning feature which requires very infrequent dismantling for the removal of the collected foreign matter from the filtering medium.

Centrifugal Purifiers

Many steel mill circulating systems will also include one or more centrifuges which are usually operated intermittently for an hour or so each day. Where large quantities of water may get into the system, however, the centri-



Courtesy of S. F. Bowser & Company, Inc.

Fig. 6 (above)—A Bowser gravity central flood lubricating system, as applied to dryer bearings of a paper machine, showing at A—receiving tank and filter; B—thermometer; C—safety valve; D—spare pump; E—service pump; F—relief valve, system protection; G—relief valve, pump protection; H—screen box; J—filter units; K—cooling coils; L—pressure switch, spare pump; M—pressure switch, service pump; N—pressure switch, low pressure alarm; O—pressure gage; P—pressure tank; Q—sight feed oilers; R—overflows (if required); S—dirty filter alarm; T—low level alarm; U—service suction; V—deep suction; W—oil supply line; X—drain line.

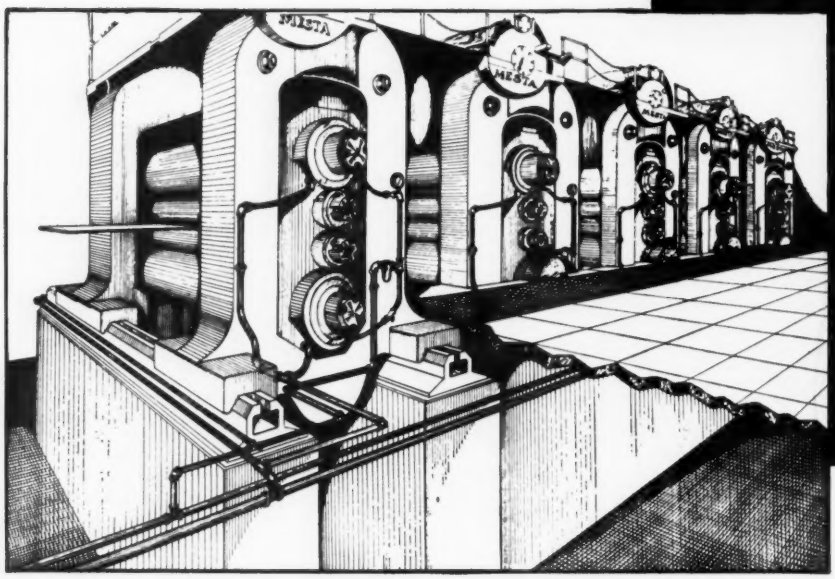
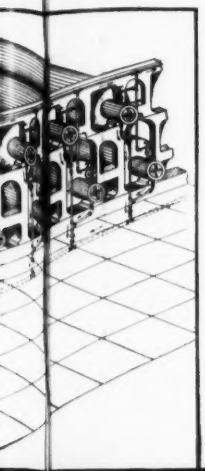


Fig. 8 (above)—Details of a Bowser ... sy... showing piping arrangement, fittings, and circu...

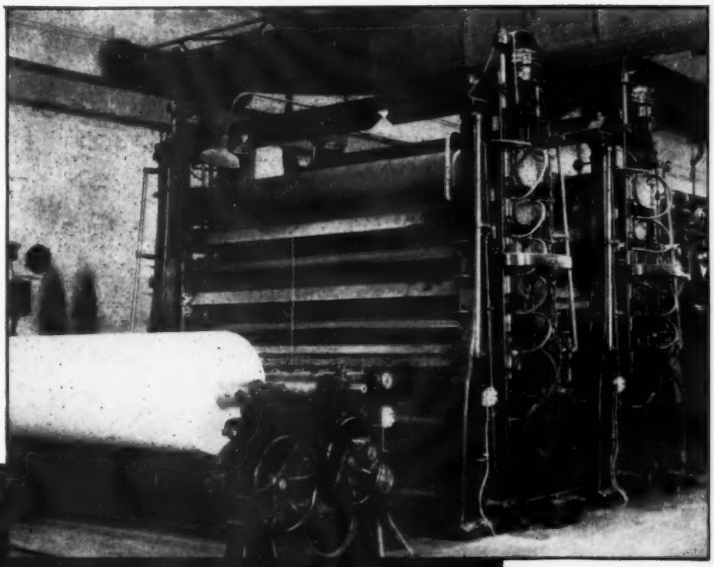
Courtesy of S. F. Bowser & Company, Inc.

Fig. 9 (above)—Typical Bowser oil piping arrangement for roll stands in steel mill service.



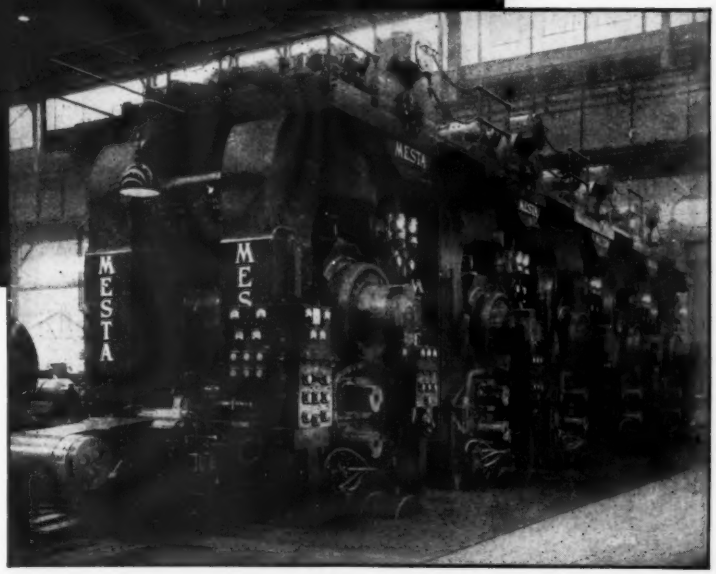
Courtesy of Rice, Barton & Fales, Inc.

Fig. 7 (right)—View of a Rice, Barton & Fales calender stack showing cooling water connections for bearings, and lubricating oil fittings. Each bearing is fed and drained separately, the bottom bearing having from four to five feeds, while the intermediate bearings each have one individual feed. Full filtration and pressure circulation of oil prevails.



Courtesy of The Bagley & Sewall Company

Bowser ring system for dryers of a Bagley & Sewall paper machine, ings, and circulating equipment.



Courtesy of Mesta Machine Company

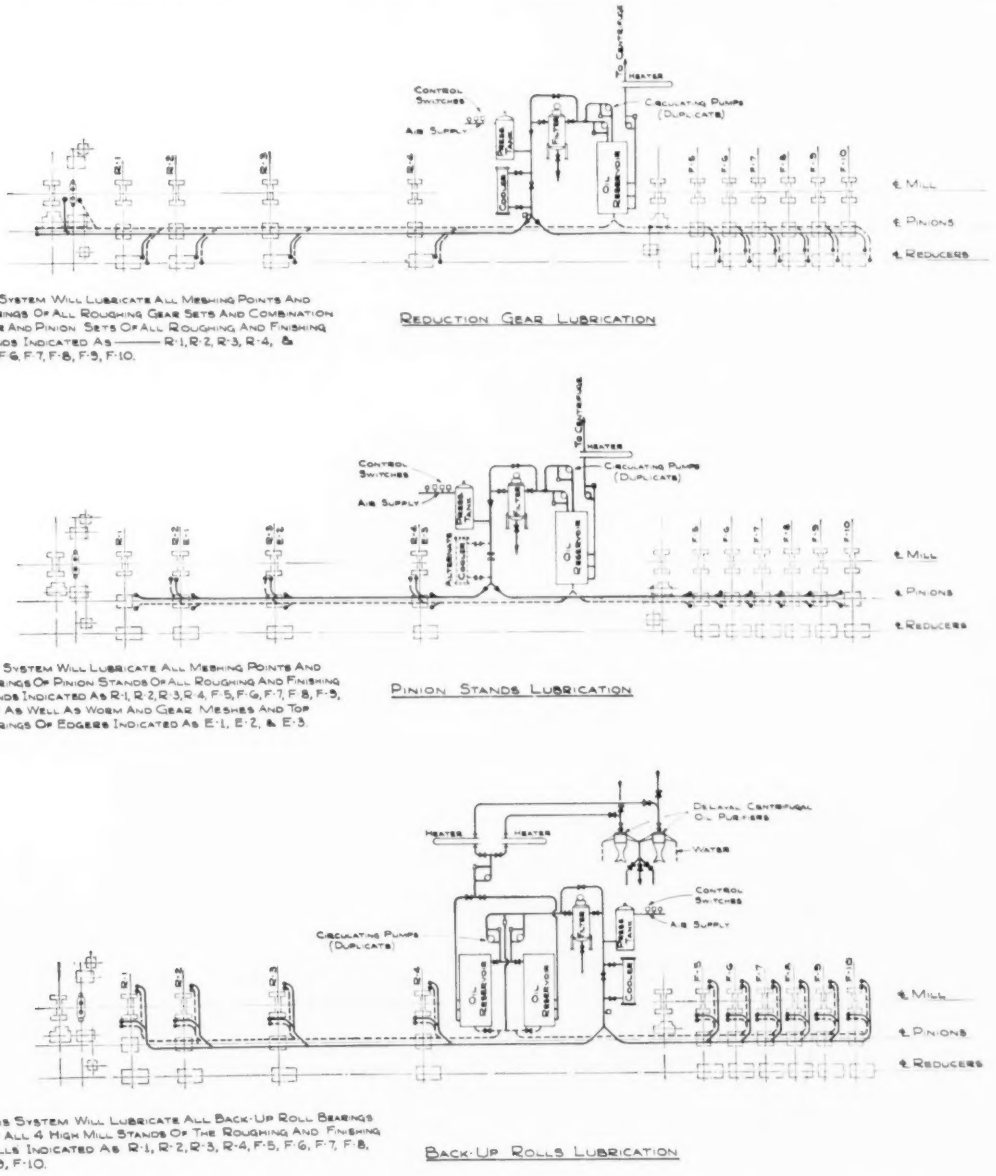
Fig. 10 (right)—A Mesta five stand mill for rolling strip steel, equipped with the Mesta oil lubricated sleeve type bearing.

fuges are sometimes run continuously until the source of the water is located, and the leak corrected.

Settling Tanks

With the possible exception of the circulating pumps, the settling tanks are the most useful and necessary features of the circulating system. Where there is any chance of considerable water getting into the system, it is advisable to install two settling tanks, so that when the oil in one tank shows signs of emulsification, the contents can be taken out of service for reconditioning. This is done by heating the oil by means of steam coils located in the bottom of the tank to a temperature sufficient to reduce the viscosity and enable the entrained water to settle to the bottom from whence it can be drawn off through the drain valves. In the paper industry, heating to around 150 degrees Fahr., prevails.

A well-designed settling tank will have



Courtesy of The De Laval Separator Company

Fig. 11—Schematic arrangement of a DeLaval pressure lubrication system for a hot strip mill, showing piping leads for reduction gear, pinion, and back-up roll lubrication.

several large clean-out valves located along the front and as near the bottom as possible. It is also desirable to slope the bottom of the tank toward the front; then by periodically opening the drain valves, the accumulation of water and sludge in the tank can be held to a minimum. Floating suctions are also often installed to allow the pumps to take the cleanest oil, which is found near the surface of the oil in the tank.

Any settling tank should be of ample size to allow the oil to flow through at minimum velocity; thus the oil entering at one end has an opportunity to drop out a considerable amount of its entrained moisture before it again reaches the pump suction at the other end. The tank should be kept as nearly full of oil as possible, due consideration being given to the expansion of the latter when heated for reconditioning purposes, because a full tank reduces the exposed surface on the inside of the tank and prevents excessive sweating; also it aids in the cooling of the oil, and allows more time for the oil to drop out its moisture.

It is good practice to alternate the service of such tanks, thus allowing a batch of oil to be in service one week, and then to rest for a week. This is a safety factor against formation of emulsions.

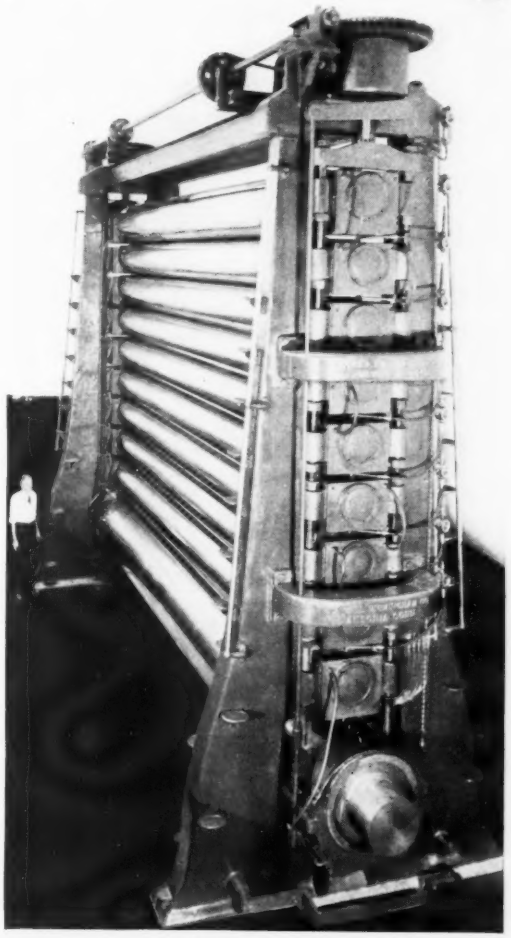
VISCOSITY-PRESSURE RELATIONSHIP

Viscosity is otherwise a factor as it may be related to the pressure developed by the circulating system, the pressure exerted upon the bearings, and the facilities for reconditioning. One of the predicates of the theory of lubrication is that oil viscosity can be reduced as the speed of the rotating parts is increased. So from a speed viewpoint only, it would be right to presume that lighter bodied lubricating oils should be used in steel and paper mill circulating systems. Certainly they would serve as more effective bearing coolants in removing surface heat by conduction. But the matter of bearing pressure also must be considered. This has increased with increase in speed, and heavier loads need greater body in the lubricating film. This required prior consideration of load-carrying capacity over heat transfer ability, for the latter can be controlled by increasing the volume of oil circulated through the system.

Load carrying capacity in a straight mineral oil is solely a function of the viscosity; hence the necessity for using high viscosity oils, especially in steel mill sleeve type bearings. So much for the reasons why the dryer end and calender stack roller bearings on a paper machine require a 750 S. S. U. viscosity oil at 100 degrees Fahr., and the Morgoil or Mesta steel mill bearing calls for an oil as high as 2500 S. S. U. viscosity.

Viscosity Defined

Now to define this term once again for the benefit of the layman. Viscosity, as a measure of the relative fluidity of a lubricant, is indicative of the body of the latter. Practically speaking, this means its ability to withstand the squeezing-out effect of pressure by virtue of the cohesion between its component molecules. This effect has been studied by research investigators, dealing with pressure as applied to lubricants within a space of definite limitations. Such conditions will rarely hold true in actual operation, for an absolutely air-tight system would be required; at least, however, laboratory conditions are partially reproduced

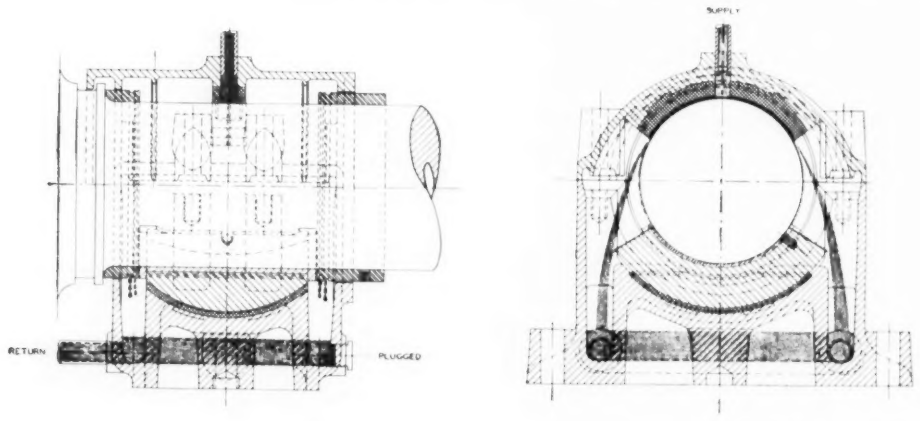


Courtesy of Farrel-Birmingham Company, Inc.

Fig. 12—End view of a Farrel-Birmingham paper calender stack showing the massive construction and roll bearing housings. Complete oil film lubrication affords adequate protection under comparatively heavy loads and high temperature conditions.

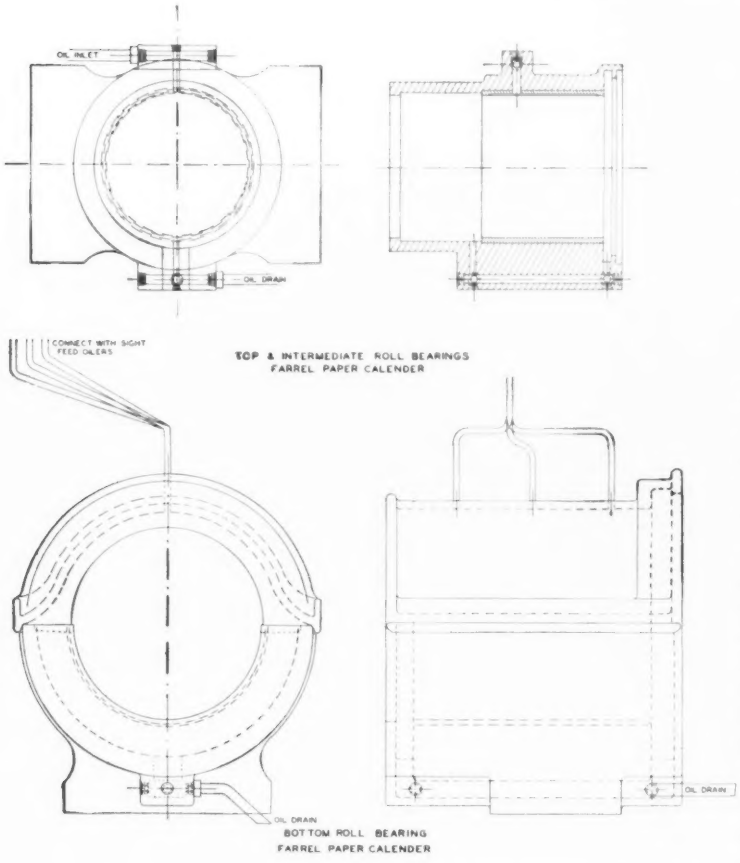
in the modern oil-tight circulating system. In other words, the lubricant will be subjected to mechanical pressure at a rate exceeding its ability to pass through the bearing. This compressive effect causes the oil to increase in viscosity; it parallels the effect of reducing the temperature, the oil becoming more sluggish.

Under high operating pressures, as developed by journal or roll neck rotation, the above should produce effective lubrication, unless the original viscosity is too high, when it might occur to an extreme. Here insufficient fluidity might mean that certain parts of a bearing might be starved.



Courtesy of The Black-Clawson Company

Fig. 13—The drive side assembly of a Black-Clawson paper mill dryer sleeve-type bearing. The path followed by the lubricating oil is shown in shaded form, from the supply inlet above the bearing through the clearance space down to the oil return below.



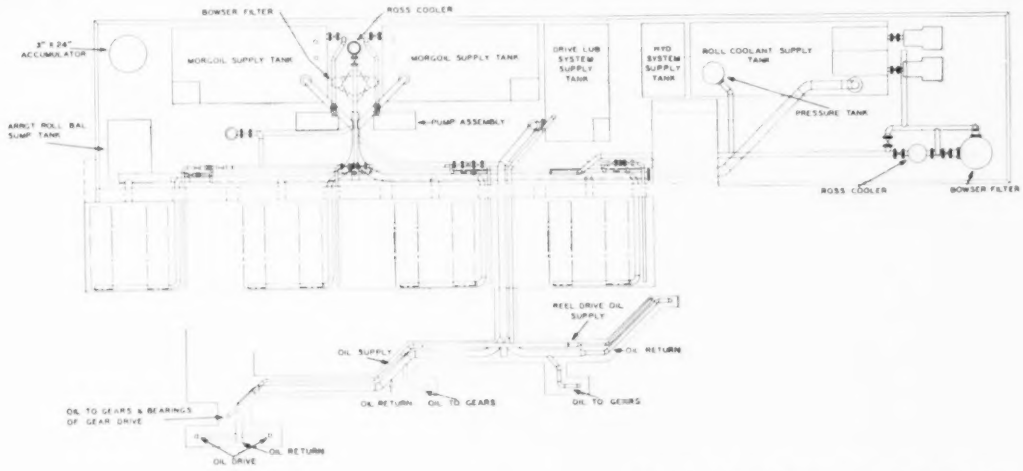
Courtesy of Farrel-Birmingham Company, Inc.

Fig. 14—Showing details of design for the top, intermediate, and bottom roll bearings on a Farrel-Birmingham paper calender. Note oil inlets and drains in each case.

Initial viscosity is measured by the time required for 60 cubic centimeters of an oil to flow through a standardized orifice at a definite and controlled temperature. Circulating oils are tested at 100 degrees Fahr., and, in addition, perhaps at 210 degrees Fahr. (for heavier products). Hence, the term 2500 S. S. U. at 100 degrees Fahr., means that 2500 seconds are necessary for 60 cubic centimeters of such an oil to flow through the Saybolt Universal Viscosimeter at 100 degrees Fahr.

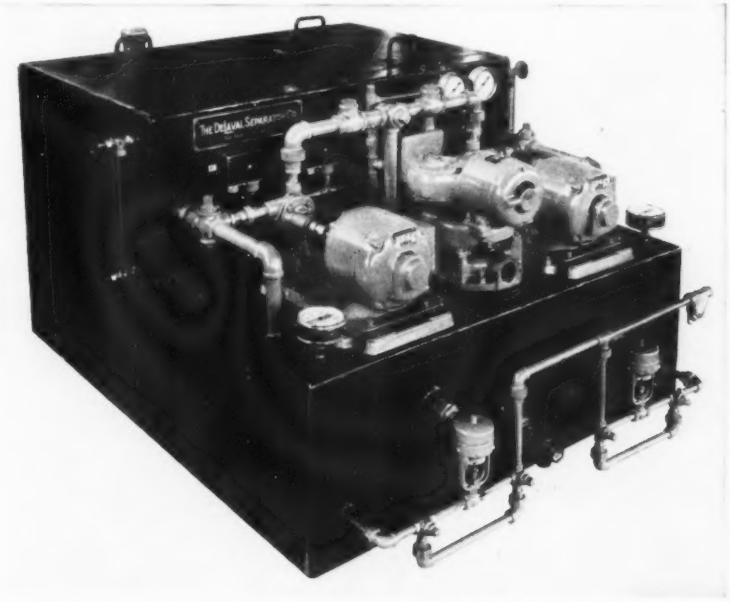
As viscosity varies inversely with temperature, increase of the latter will cause the oil to become more fluid. This is an important fact when an oil is

to be selected for high pressure or high temperature service. It has a bearing on the actual "operating viscosity." So where operating temperatures may be prevailingly high, the initial viscosity of the oil must be selected so as to develop a probable safe "operating viscosity." On the other hand, where adequate bearing cooling is practicable, the operating temperatures are more readily controlled; this also holds true where a suitable reconditioning system is employed to keep the oil free from non-lubricating accumulations of oxidized or metallic foreign matter, viz., the satisfactory lubrication of paper mill dryer bearings with a 750 S. S. U. viscosity oil at 100 degrees Fahr., even though live steam may be passing continually through the roll necks.



Courtesy of United Engineering and Foundry Company

Fig. 15—Plan view and piping arrangement of a United 4-HI tandem cold mill, showing lubricating equipment in the oil cellar; also oil leads and returns.



Courtesy of The De Laval Separator Company

Fig. 16—View of a De Laval Dual Unilube system. This device, being self-contained as to pumps, centrifuge, motive power, and storage tanks, is valuable in maintaining oil protection in certain types of steel and paper mill installations.

POUR TEST SIGNIFICANCE

Relative fluidity, as measured by the viscosity and pour test, must also be carefully considered whenever low temperatures may prevail; it becomes highly important in conjunction with the pressure available.

The pour test used to require particular consideration, for in cold weather or under low temperature starting conditions in exposed mills, the rate at which the oil could be returned to the settling tanks was affected. Should it become too sluggish at any time, flow-off from a pinion housing or bearing might be impaired, to develop backing up of the oil in the system. Furthermore, if any bearings were improperly sealed, oil might leak from the case. This would result in waste, also a sloppy condition on the operating floor.

The modern pressure oil circulation system, however, provides for the use of heating elements and the elimination of oil baths; this has materially decreased the importance of the pour test. On the other hand, where either the viscosity or pour test is too high, the reduced fluidity may develop marked increase in power consumption. This would prevail throughout the system, for not only would the circulating or oil delivery pumps be called upon to do extra work, but also the mill drives might feel the extra duty demanded due to the increase in internal friction within the lubricant itself.

Increase in the automatic nature of the lubricating system requires even more careful consideration of relative fluidity. With extensive piping layouts and the possibility of abnormal friction losses occurring within the system itself, reduction in oil flow may result to a sufficient degree to require severe overloading of the pumps in order to keep the oil in the supply tanks at the proper level, and deliver the required amount to the bearings.

OIL PROTECTION

Lubricating oils for the circulating oiling systems applied to the drive gears and roller bearings on the paper machine, and on certain types of enclosed gearing and the modern sleeve-type flood lubricated steel mill roll neck bearing, must be most carefully protected to assure of continued lubricating ability. Sludge is an ever present possibility if bad water conditions prevail. This is why bearing and mill manufacturers include such effective methods of sealing against entry of water, also solid foreign matter, which, likewise, is a deterrent to good lubrication.

Regardless of these precautions, however, water will gain entry. The only recourse, therefore, is to remove it before it can lead to the formation of emulsions and certain types of sludge. This is where the reconditioning system and oil filter play a most important part. In a relatively water-free system, however, sludge can be present in the absence of an emulsion, especially in an oil readily susceptible to oxidation. Furthermore, sludges can be either water-soluble, or oil-soluble.

Emulsions are largely prevented by continuous removal of water; along with sludges, they can be eliminated by centrifugal purification. Filtration, in turn, will remove solid contaminants and oxidizable material. The use of the centrifuge, plus automatic and continuously cleaned filtration, is practiced in the steel industry; the bag or screen type filter in turn predominates in the paper mill. In any filtering element, the uniformity of the filtering media must be maintained; in other words, variation in pressure drop across the filter media due to plugging is not desirable.

The amount of water which will be present at certain stages of steel mill and paper machine operations is considerable; furthermore, this water is usually contaminated. Water is one of the primary agents in heavy duty steel rolling mill service in eliminating scale accumulation. Much of this water will deluge the bearings and drives. After passing over the hot metal, it is dirty and of sufficiently high temperature to work its way into the lubricating system, almost regardless of the care in design. Furthermore, at a temperature of very nearly the boiling point, water will have a decided tendency to react physically with any oil with which it comes in contact, to cause formation of permanent emulsions which may be very difficult to break. The wet end and press roll section of the paper machine presents a similar water condition, though the temperature is usually lower.

Water traps and settling tanks in the circulating system have been found to aid materially in removing a considerable amount of this water before it has time to affect the oil. All points wherein water may gain entry into such a lubricating system should be carefully sealed as added insurance. In steel mill gear sets this can be accomplished sometimes by caulking surface joints with oakum, and covering with molten lead.

With bearings, however, attention should be directed to their original design, in order to provide for some recognized method of sealing, which will not impair the free rotation of the shafts. The roller bearing designer has achieved outstanding success in working with the paper industry. Some of the newer paper machines are so completely equipped with sealed roller bearings and oil filtration that the color of the oil in circulation is scarcely changed after months of operation.

Methods of Sealing

Modern sealing methods have also been carefully studied to determine their adaptability to the oil lubricated sleeve type bearing. The perfected design of this bearing will rarely permit the entry of an excess of actual solid foreign matter; water leakage, however, may occur, or there may be some accumulation due to condensation. Seal investigation has, therefore, been directed towards reducing this water content. As already stated, brass rings, the expanded leather cup, and the compression type of rubber seal, have all proved their adaptability, and are widely used today for the protection of such bearings. The result has been very gratifying.

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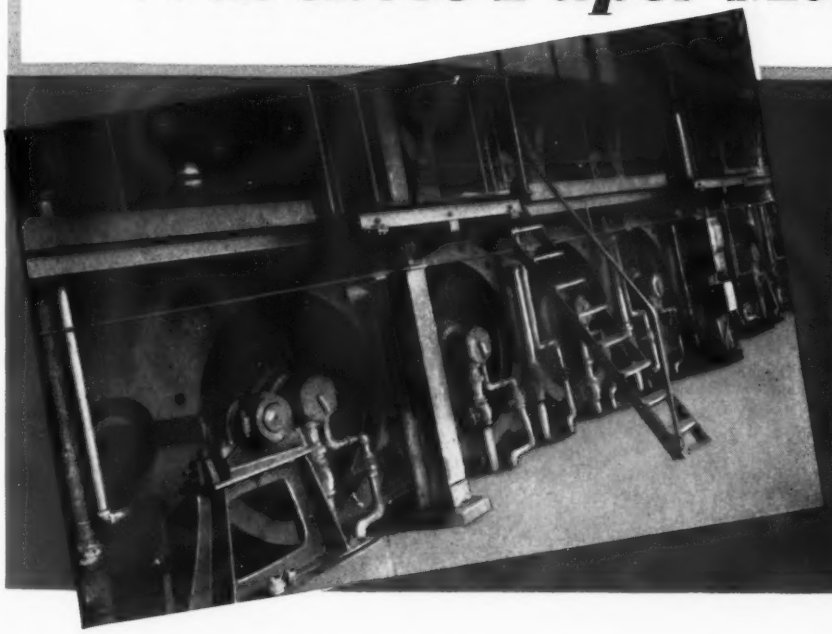
OIL LINES FREE FROM SLUDGE

. . in these Paper Mills



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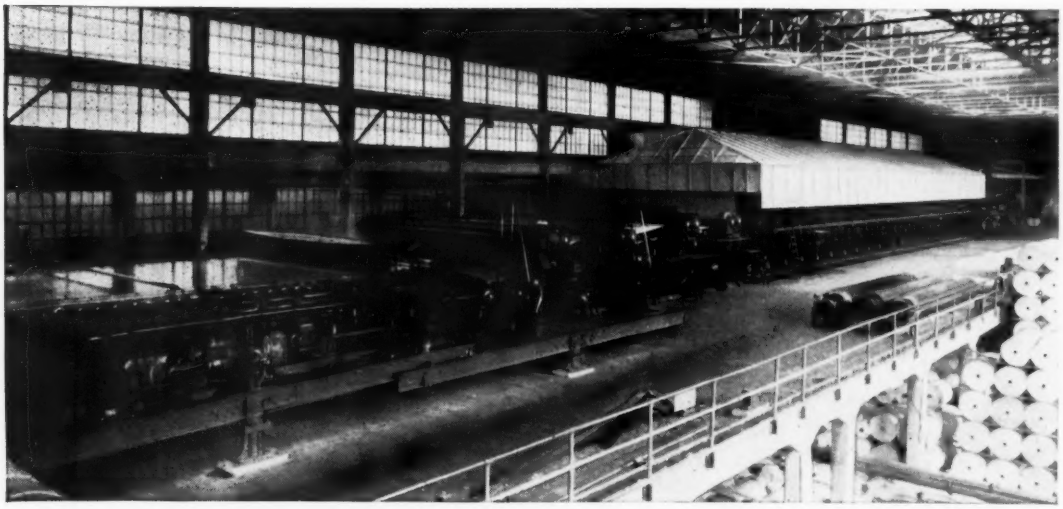

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